(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 December 2003 (31.12.2003)

PCT

(10) International Publication Number
WO 2004/001476 A1

(51) International Patent Classification[7]: G02B 6/42

(21) International Application Number: PCT/GB2003/002553

(22) International Filing Date: 13 June 2003 (13.06.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0214366.7 21 June 2002 (21.06.2002) GB

(71) Applicant *(for all designated States except US)*: **PI PHOTONICS LIMITED** [GB/GB]; 26 Cambridge Science Park, Milton Road, Cambridge CB4 0FP (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **BETTS, Ralph, Alexander** [GB/GB]; 36 North End, Meldreth, Cambridge SG8 6NT (GB). **BRICHENO, Terry** [GB/GB]; Moorland View, High Street, Great Stampford,, Saffron Walden, Essex CB10 2RG (GB). **ROBERTSON, Alexander** [GB/GB]; Mount View, Mill Lane, Stebbing, Dunmow, Essex CM6 3SN (GB).

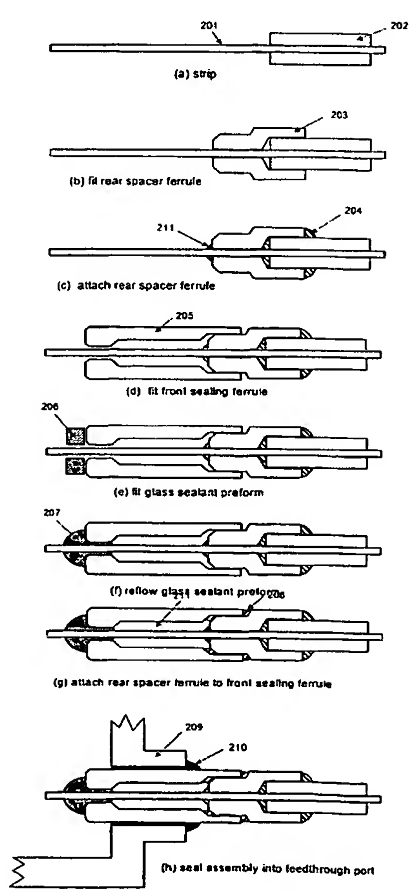
(74) Agent: **CUTFORTH, Peter**; Impetus, Grove House, Lutyens Close, Chineham Court, Basingtoke, Hampshire RG24 8AG (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),

[Continued on next page]

(54) Title: HERMETIC OPTICAL FIBRE FEEDTHROUGH ASSEMBLY



(57) Abstract: High reliability hermetic optical fibre feedthroughs suitable for single fibre and multiple fibres and polarisation maintaining fibres where the seal to the fibres is effected by glass soldering in an arrangement involving two interpenetrating, closely fitting and substantially coaxial ferrules (203 and 205), that protects the fibre or fibres from adverse stresses resulting either from temperature cycling or from asymmetrical reflow of the sealant material.

WO 2004/001476 A1

Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

HERMETIC OPTICAL FIBRE FEEDTHROUGH ASSEMBLY

Field of the Invention

The invention relates to the provision of a hermetic design of optical fibre feedthrough, suitable for single fibres or multi-fibre ribbons. The hermetic fibre feedthrough assembly (fta) may then be employed in the construction of hermetic packages for active or passive optical components finding application in optical fibre telecommunication systems and networks, whereby the component, sealed in a controlled atmosphere, is afforded protection against deleterious effects of, for example, humidity in the ambient environment. The invention is also applicable to polarisation maintaining (pm) fibres.

Background to the Invention

Several methods have been proposed for effecting a hermetic seal round optical fibres (1,2,3,6,8), all of which involve access to the silica surface by removal of any protective polymer coating. This renders the fibre more prone to mechanical failure by stress-induced growth of surface flaws, and so it is necessary to protect any exposed fibre surface from induced stresses (for example caused by buckling of the fibre in the assembly resulting from grow-out in the external pigtail, or caused by tensile or torsional strains transmitted as a result of movement of the external pigtail). These effects are exacerbated close to the hermetic seal, where the compressive collar formed by the sealant material causes localised regions of tensile stress in the surface of the fibre (9). Paschke et al (5) employ a glass capillary to inhibit buckling, and Eales et al (4) use an epoxy vacuum backfill technique to provide the necessary protection.

The high local stresses associated with forming a hermetic seal can also inhibit the polarisation maintaining ability of pm fibres if the symmetry of the sealing region is not maintained. Donaldson and Freer (7) address this issue by controlling the wetting of a solder seal using patterned metallisation on the fibre.

Figure 1 (a) shows a typical prior art embodiment, where a hermetic seal is provided by the reflow of a sealant material (104) at the front of a ferrule of substantially constant bore (103) and mechanical support for the stripped fibre (101, 102) behind the seal is

provided by vacuum backfilling the rear of the ferrule with an appropriate adhesive (105).

Figure 1 (b) illustrates uneven wetting of the sealant material (106)(caused by capillary action of the sealant if the fibre is not precisely centred in the bore of the ferrule), one effect of which is to give rise to non-symmetric (lateral) stresses on the fibre (101) and hence inhibit the polarisation maintaining ability of pm fibre.

Figure 1 (c) illustrates a trapped void (107) in the backfilled adhesive (caused by deficient vacuum backfill procedure). In such a configuration, the void provides a compliant surface for the accommodation of differential thermal expansion between the adhesive (105) and the ferrule (103), and the resulting strains on the fibre (101) can give rise to temperature dependent bend loss, temperature dependent changes in the polarisation maintaining ability of pm fibre and even fracture of the fibre.

Figure 1 (d) illustrates the generation of a void (109) in a backfilled ribbon fibre fta (caused by asymmetric failure of the bond between the backfilled adhesive and the internal surface of the ferrule (108) as a result of the shrinkage of the adhesive upon cure or the differential expansion between the adhesive and the ferrule in cooling from an elevated cure temperature, or both, expressed across the width of the array of fibres). The effect of such a shrinkage void is to place high shearing stresses on the fibres adjacent to the void, which can result in bend loss, temperature dependent bend loss, loss of polarisation maintaining ability of pm fibres and fibre fracture.

Background Art References

1. US 4 119 363 (1976) Camlibel and Rich.
Soldering round bare fibre in a metal tube to effect compression seal.

2. US 4 252 457 (1978) Benson, Camlibel, MacKenzie and Rich.
Swaging annealed metal ferrule round bare fibre to effect compression seal.

3. US 4 357 072 (1980) Goodfellow and Carter.
Soldering to metallised fibre in SLED package and subsequently adjusting alignment of fibre to SLED.

4. GB 2 124 402 (1983) Eales, Leggett, Ashton and Bricheno.
Au/Sn soldering to metallised fibre in laser package.

5. US 4 904 046 (1989) Paschke, Kreutzmann and Hack.
Glass soldering to bare fibre and providing glass tube to inhibit buckling.

6. US 5 155 795 (1991) Wasserman and Kerek.
Glass soldering to metallised fibre in two-part metallic ferrule.

7. US 5 664 043 (1997) Donaldson and Freer.
Soldering to (patterned) metallised fibre to control symmetry of (and hence stress applied by) solder fillet.

8. "Electroless plating of optical fibers for hermetic feedthroughs", Watson et al, Proc. Elect. Comp. & Tech. Conference (2000), p250.
Soldering to fibre plated with solderable Ni-P in Kovar ferrule.

9. "The circular cylinder with a band of uniform pressure on a finite length of the surface". Barton, Journal of Applied Mathematics, 8, pp A97 - A104, 1941.

10. "Strength of Materials ", Timoshenko, (Krieger, 1956). Part II, Chapter V.

Summary of the Invention

The object of the invention is to provide improved methods addressing the above mentioned issues. The invention provides methods as set out in the claims, and can provide a method of forming a hermetic seal round one or more optical fibres in a feedthrough assembly that also provides protection against adverse stresses resulting from mechanical movement of the associated pigtail or thermal cycling of the assembly or asymmetric distribution of the sealant material.

The embodiments of the present invention differ from prior approaches in four notable aspects. First, the functions of mechanical support and hermetic sealing are separated into two ferrules (the rear 'spacer' ferrule and the front 'sealing' ferrule), thus allowing independent control and optimisation of these two functions. Second, the wetting of the

hermetic sealing glass is controlled by the geometry of the sealing ferrule in the region of the seal. Third, the fit and geometry of the two ferrules is arranged such that when the ferrules are attached together in a final assembly stage, the attachment adhesive is reliably prevented from wetting into the critical space behind the hermetic seal. Fourth, a coating is provided for the waveguide where it issues from the hermetic seal, to act as a bend limiting feature, to protect the waveguide from damage. This is particularly useful where the seal and an optical device is assembled and attached to the waveguide outside a package and later inserted into the package and the seal is attached to the package.

In particular:

(i) some examples of the invention incorporate the pre-assembly of a rear ferrule component on to stripped fibre in order to provide inspectable, good support of stripped fibre against buckling, tensile or torsional strains.

(ii) some examples of the invention incorporate a close fitting rear ferrule insert in order to control the wetting of the adhesive that attaches the rear ferrule to a front ferrule, thus avoiding asymmetric adhesive filling or asymmetric voids (and thereby avoiding adverse stresses on the fibre resulting from differential thermal expansion between the adhesive and the front ferrule during thermal cycling) without the need for vacuum backfill.

(iii) one embodiment of the invention incorporates a bead feature on the rear ferrule insert that can ensure an interference fit between rear ferrule insert and front ferrule, thus further aiding control of wetting of the adhesive that attaches the rear ferrule to the front ferrule.

(iv) one embodiment of the invention incorporates a vent port in the front ferrule wall that prevents differential pressure being generated across the adhesive that attaches the rear ferrule insert to the front ferrule during cure (as a result of temperature variations during the curing process), ensuring good fill of the attaching adhesive between the two components.

(v) a further embodiment of the invention incorporates a reinstated coating bend limiter in order to provide additional protection to the stripped fibre where it leaves the hermetic seal

(vi) some examples of the invention incorporate a stepped bore at the hermetic sealing end of the front ferrule in order to control wetting of the reflowed sealant material, ensuring substantially symmetrical radial stress on the fibre or fibres and thereby avoiding degradation of the polarisation maintaining capability of pm fibres.

(vii) the embodiments of the invention including the processes described below are readily adaptable to provide 'in-line' hermetic ftas.

In summary, the embodiments of the invention can provide a design and a manufacturing method for reliable, hermetic ftas for single fibres, multi-fibre ribbons and polarisation maintaining fibres that is simple, rapid and tolerant both of variations in piecepart dimensions and of process fluctuations.

Any of the features of dependent claims can be combined together or combined with any of the independent claims. Other advantages to those set out here may become apparent, particularly over other prior art not known to the inventors.

Brief description of the drawings

Figure 1 (a) to (d) shows some of the prior art problems that are addressed in the described embodiments of the present invention.

Figure 2 (a) to (h) shows the assembly sequence of a hermetic feedthrough according to an embodiment of the present invention.

Figure 3 (a) and (b) shows the side and top views of a ribbon fibre hermetic fta, constructed according to an embodiment of the present invention.

Figure 4 (a) to (c) shows a variation of the assembly employing a modified rear ferrule insert.

Figure 5 (a) to (c) shows a variation of the assembly employing a modified front ferrule.

Figure 6 (a) to (c) shows a variation of the assembly employing a crimp between the front ferrule and the rear ferrule insert.

Figure 7 shows a variation of the assembly employing a partially reinstated coating to act as a bend limiter.

Figure 8 shows a variation of the assembly employing a partially reinstated coating moulded in place to act as an internal bend limiter.

Figure 9 (a) to (h) shows a variation of the assembly sequence that provides an in-line hermetic feedthrough according to an embodiment of the present invention.

Figure 10 (a) to (e) shows an assembly sequence for an optical device assembly having hermetic feedthrough according to an embodiment of the present invention.

<u>Detailed description</u>

The design and assembly sequence of one embodiment of the invention is described with reference to Figure 2.

First, (Figure 2 (a)), all polymer sleeving (202) (if any is present) is stripped from a short region of the fibre (201). The invention is also applicable to waveguides such as fibres with no sleeving, to bare fibre, or fibres with other coatings which are suitable for receiving a seal.

Then, (Figure 2 (b)), the stripped region is inserted into a rear spacer ferrule (203). The material for the rear ferrule is chosen to satisfy the conditions that the dimensions can be accurately controlled during manufacture, that the ferrule is mechanically stable during the temperature excursions consequent upon later soldering of the completed fta into a package, and that the surface of the ferrule can form a reliable bond to the adhesive employed to fix the fibre into the rear ferrule. Thus the rear ferrule could be provided as a moulding of a high temperature engineering polymer such as Liquid Crystal Polymer (LCP) or Polyetheretherketone (PEEK) or Polyimide, or as a swaged tube formed from a suitable alloy such as Kovar, or as a metal injection moulding (MIM) of a suitable alloy. Preferably, the rear ferrule should be arranged to accommodate a short length of the unstripped fibre polymer coating.

Then, (Figure 2 (c)), the fibre is attached within the rear ferrule using a suitable adhesive (204), for example thermosetting epoxy. Preferably, the adhesive is applied to the rear of the assembly at a temperature such that the adhesive is drawn into the assembly by capillary action. The appearance of a fillet of uncured adhesive (211) at the front of the ferrule then provides inspectable assurance that the adhesive has filled the interior of the subassembly, when the cure may progress to completion.

Then, (Figure 2 (d)), the front sealing ferrule (205) is slid over the stripped fibre to engage with the rear spacer ferrule. The front ferrule is provided with a stepped bore

(212) at the front end that will subsequently serve to limit the extent of reflow of a sealing glass. The front ferrule may be also be provided with a further stepped bore (213) at the rear end, or the rear ferrule with a stepped outer surface (214), or both, in order to set the extent of interpenetration of the ferrules. The material of the front ferrule is chosen to satisfy the conditions that its coefficient of thermal expansion is matched to or higher than the coefficient of thermal expansion of the solder glass used to effect the hermetic seal, and that its surface finish is compatible with the formation of a hermetic bond to the reflowed glass sealant. Suitable alloys are Kovar or NILO48 and a suitable surface is formed by electoplating Ni followed by Au. The front ferrule may be formed by conventional machining, or by spark erosion or as a swaged tube or as a MIM moulding.

Then, (Figure 2 (e)), a solder glass preform (206) is fitted over the stripped fibre. The solder glass is typically formed from a high lead content fusible matrix bearing high melting point ceramic filler materials to achieve the required coefficient of thermal expansion. Other sealing methods can be used, such as metal solders in conjunction with metallised fibres.

Then, (Figure 2 (f)), the solder glass preform is heated to reflow round the fibre and wet into the front bore of the front ferrule, thus forming a hermetic seal (207). The required heating may be conveniently supplied by RF induction heating of the front portion of the front ferrule, with the ferrule mounted with its long axis substantially vertically, such that the glass preform rests in contact with the front surface of the ferrule. At an appropriate reflow temperature, the distribution of the fused sealant glass is determined by surface tension effects and limited by its viscosity. By the choice of an appropriate time-temperature profile for the reflow process and appropriate dimensions for the internal bore of the front ferrule, the glass sealant can be controlled to flow along the small bore at the front of the front ferrule and stop at the step in the internal bore so as to form a symmetrical distribution of the sealant glass round the optical fibre. For a 125um fibre in a single fibre fta, an appropriate minimum bore is in the region 150um - 350um, and an appropriate length of the minimum bore is 1mm.

Then, (Figure 2 (g)), the rear spacer ferrule is attached to the front sealing ferrule, using a suitable adhesive (208), for example thermosetting epoxy. A controlled amount of adhesive is dispensed at the junction between the two ferrules, and the subsequent distribution of the uncured adhesive is determined by surface tension effects and limited by its viscosity. If the temperature of the assembly is maintained such that the viscosity

of the uncured adhesive is low (typically <100Pa.s), then the distribution of the adhesive is determined almost entirely by capillary action. The mechanical fit between the front and rear ferrules is controlled to be typically <100um, when capillary action ensures that the uncured adhesive reliably wets to the front extreme of the rear ferrule, *but no further*, filling the space between the two ferrules in the region of ferrule interpenetration. The cure of the adhesive is then progressed to completion. This assembly sequence ensures that an adhesive-free void (211) is maintained around that portion of the stripped fibre between the rear spacer ferrule (203) and the hermetic seal (207) at the front of the front sealing ferrule (205). The length of unsupported fibre is chosen such that in axial compression, under all conditions of axial offset of the two ferrules allowed by tolerancing considerations, the fibre is maintained in a state of elastic stability against buckling (10).

This completes the assembly sequence of the fta.

Subsequently, (Figure 2 (h)), the fta may be threaded into a feedthrough port (209) in the wall of a component package and soldered in place (210) to complete the process of providing hermetic fibre access through a package wall.

Figure 3 (a) and (b) shows side and top views of a four-fibre ribbon fta constructed according to the process outlined above.

Figure 4 shows the use of a modified rear spacer ferrule design that can ease the tolerances required for an adequate fit between the two ferrules. In this embodiment, the front edge of the rear ferrule (401) is provided with a peripheral 'bead' feature (402) that forms an interference fit with the rear of the front ferrule (Figure 4 (a)). In principle the bead could be on either of the ferrules, or other geometries could be used to achieve the interference fit. Upon insertion, the bead deforms (Figure 4 (b)), and serves both to centralise the rear ferrule in the front ferrule (providing a more uniform gap between the ferrules and hence better control of capillary action backfill) and to provide a further impedance to flow of the attachment adhesive beyond the front of the rear ferrule (Figure 4 (c)).

Figure 5 shows the use of a modified front ferrule (501) that is provided with a venting port (502). In principle, the vent port could be located in either the rear or the front ferrule. The vent port prevents the pressure of partially trapped air in the void space

(505) at the rear of the front ferrule differing significantly from the ambient. First, this effectively prevents the generation of tensile strains on the fibre by any 'piston' action of a closely fitting rear ferrule during the rapid high temperature excursions associated with glass sealant (503) reflow (Figure 5 (a)). Second, the vent renders the distribution of the uncured attachment adhesive (504) immune to any influence of differential pressures consequent upon temperature variations of the assembly during dispense and cure (Figure 5 (b) and (c)), allowing the distribution of the attachment adhesive to be completely determined by capillary action, as outlined above.

Figure 6 shows the use of a modified assembly procedure whereby after insertion of the rear ferrule into the front ferrule, a light multipoint crimp (601) is applied to the front ferrule over the region of interpenetration. Again, in principle, the crimp could be located on either the rear or the front ferrule as desired.
This serves to centralise the rear ferrule in the front ferrule (providing a more uniform gap between the ferrules and hence better control of capillary action backfill) and also provides re-entrant features on the internal surface of the front ferrule that, when the attachment adhesive is cured in place, provide greater immunity of the assembly to tensile forces applied to the external fibre pigtail.

In some packaging configurations, the stripped fibre leaving the internal side of the hermetic sealing region may be subject to bending stresses, for example in order to accommodate misalignments between the feedthrough port and the internal attachment of the fibre to the packaged component. In these circumstances, the additional peak tensile stresses associated with the bent fibre cantilever tend to occur at the point where the fibre leaves the support of the sealant material, adding to the surface tensile stresses already present as a result of the compressive collar formed by the sealant material. This problem can be avoided by providing the fibre with additional mechanical support in this region effectively displacing the region of peak bending stress away from the region of peak collar stress.

Figure 7 shows an additional process step whereby the stripped fibre (701) leaving the internal side (702) of the hermetic seal is afforded additional protection against bending stress by the provision of a partially reinstated coating formed by a cured bead (703) of, for example, a uv-curable acrylate resin similar to that used as a primary coating on the pristine fibre.

Figure 8 shows a different embodiment of the partial reinstatement process, whereby the fta assembly is placed in a specially constructed mould (801), similar to that used for coating reinstatement around a fused fibre splice (Figure 8 (a)). Reinstatement resin (802) is then injected into the mould and cured, for example by exposure to uv radiation through a partial mask (803) (Figure 8 (b)). The mould is then split away to leave the bend limiting feature (804) in place (Figure 8 (c)).

In some packaging configurations, it may be required to route longer fibres within the hermetic package, for example in order to gain access to different locations on the periphery of a packaged component by fibres entering through a common feedthrough port. In these circumstances, it is preferable not to remove the protective polymer coating from those portions of the fibres forming the internal connections, and it is therefore necessary to form a hermetic seal 'in-line' on a centrally stripped portion of the fibre.

Figure 9 shows how the assembly procedure according to the present invention may be adapted to provide an 'in-line' hermetic fta. The fibre is first stripped of its polymer coating (902) over a short central region (901) (Figure 9 (a)). The assembly then proceeds essentially as outlined above (Figure 9 (b) to (f)), except that the rear spacer ferrule (903), the front sealing ferrule (904) and the sealant glass preform (905) are all provided with minimum internal bores that exceed the dimensions of the unstripped fibre coating - typically 250um - such that these components may be threaded into position over the stripped portion of the fibre. In a final assembly stage (Figure 9 (g)), the short length of stripped fibre (906) remaining at the internal end of the hermetic seal (907) is protected from bending stresses by the reinstatement of the coating (908) according to one of the methods outlined above.

Subsequently, (Figure 9 (h)), the fta may be threaded into a feedthrough port (909) in the wall of a component package and soldered in place (910) to complete the process of providing hermetic fibre access through a package wall.

Figures 10a to 10e show an example of a sequence of assembly steps for an optical device 945 in a hermetically sealed package 950. First a pair of ftas 930 are assembled, each having bend protection on one side. This can be implemented using the methods described above, or other methods. At fig 10b, there is shown an optical device 945 assembled and attached to recoated fibre on the sealed side of the ftas. This is easier

to accomplish outside the package. At fig 10c the assembly is inserted into the package. The package has apertures in the sides, and one end of the assembly is inserted by threading through a first aperture. At figure 10d, the other end of the assembly is inserted into the other aperture. This normally involves some bending of the assembly, unless the package is made longer than the assembly, which is usually impractical. The bend protection at the fta seals enables this bending to be achieved with less risk of damage, and without needing other more expensive fibre supports. The weakest point is often the point where the fibre leaves the seal, where the compressive collar formed by the sealant material causes localised regions of tensile stress in the surface of the fibre, thus rendering the fibre more susceptible to cracking. At fig 10e the ftas are sealed in the apertures following established practice, and the package lid can be used to close the package. Variations of the method include use with single ended devices, or devices having more than two fibres, or apertures at different places in the package, for example. Clearly some of the optical device assembly can be completed after the insertion into the package.

As has been described above, a high reliability hermetic optical fibre feedthrough is provided, suitable for single fibre and multiple fibres and polarisation maintaining fibres where the seal to the fibres is effected by glass soldering in an arrangement involving two interpenetrating, closely fitting and substantially coaxial ferrules (203 and 205). This arrangement can protect the fibre or fibres from adverse stresses resulting either from temperature cycling or from asymmetrical reflow of the sealant material.

It will be appreciated by those skilled in the art that although the invention has been described with reference to specific examples, the invention may be embodied in many other forms without departing from the scope of the claims.

Claims

1. A hermetic optical waveguide feedthrough assembly comprising at least one optical waveguide that has been stripped of any polymer coating and that is located within and substantially parallel to the axis of a first ferrule and that is sealed to a first end of the first ferrule by means of a sealing material and that is also located within and substantially parallel to the axis of a second ferrule to which the said waveguide is attached by a first adhesive bond.

2. The hermetic optical waveguide feedthrough assembly according to Claim 1, where the sealing material is a reflowed glass sealing material.

3. The hermetic optical waveguide feedthrough assembly according to Claim 1 or Claim 2, where the second ferrule is attached by a second adhesive bond to the second end of the first ferrule over a region of mutual interpenetration of the ferrules, and the quality of the fit between the two ferrules is such that the distribution of the second adhesive during dispense and cure is constrained by capillary action to the region of overlap between the two ferrules, thereby ensuring that the length of stripped optical waveguide between the hermetic seal to the first ferrule and the attachment to the second ferrule is maintained free of attachment adhesive.

4. The hermetic optical waveguide feedthrough assembly according to Claim 3 or any preceding claim, where the second ferrule is positioned to wholly enclose the transition between the stripped and unstripped portions of the said waveguide or waveguides.

5. The hermetic optical fibre feedthrough assembly according to Claim 4 or any preceding claim, where the second ferrule is additionally provided with a stepped bore to ensure positive positioning of the second ferrule such that the transition between the stripped and unstripped portions of the said waveguide or waveguides is wholly enclosed within the second ferrule.

6. The hermetic optical waveguide feedthrough assembly according to Claim 4, or any of claims 1 to 3 where the second ferrule is additionally provided with a beaded feature within the region of interpenetration with the first ferrule, or the first ferrule is provided

with such a beaded feature, such that an interference fit is ensured between the first ferrule and second ferrule over all the tolerance limits of the two ferrules.

7. The hermetic optical fibre feedthrough assembly according to Claim 4 or any preceding claim, where the first or the second ferrule is additionally provided with a venting aperture.

8. The hermetic optical waveguide feedthrough assembly according to Claim 4, or any preceding claim where the first or the second ferrule is additionally provided with a light multipoint crimp to establish an interference fit between the first ferrule and the second ferrule over all the tolerance limits of the two ferrules.

9. The hermetic optical waveguide feedthrough assembly according to Claim 4, or any preceding claim, where the first end of the first ferrule incorporates a stepped bore to act as a limiting feature in controlling the wetting of the reflowed sealing glass material.

10. The hermetic optical waveguide feedthrough assembly of any preceding Claim, where the stripped waveguide issuing from the hermetically sealed end of the first ferrule is additionally provided with a region of reinstated polymer coating to act as a bend limiting feature.

11. The hermetic optical waveguide feedthrough assembly of any preceding Claim, where the bores of the first ferrule, the second ferrule and the sealing glass preform can accommodate the unstripped waveguide or waveguides, thereby allowing the assembly of a hermetic feedthrough at a region of centrally stripped waveguide to form an in-line hermetic feedthrough assembly.

12. The hermetic optical waveguide feedthrough assembly of any preceding Claim, the waveguide accommodating multiple fibres formed in an array.

13. A hermetic optical waveguide feedthrough assembly having a first ferrule around the waveguide, a sealing material between the first ferrule and the waveguide, and a second ferrule around the waveguide, attached to the waveguide and spaced apart from the sealing material.

14. A hermetic optical waveguide feedthrough assembly having a ferrule around the waveguide, and a sealing material between the ferrule and the waveguide, the ferrule having a geometry in the region of the seal such that wetting of the sealing material is controlled by the geometry of the sealing ferrule in the region of the seal.

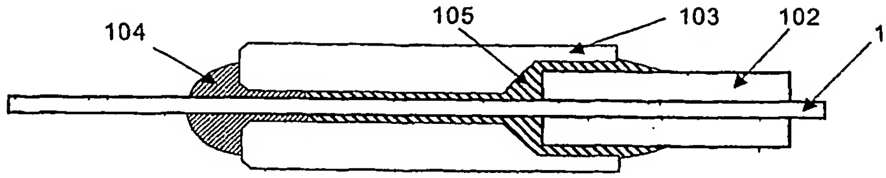
15. A hermetic optical waveguide feedthrough assembly having a one-piece or multi-piece ferrule around the waveguide, a sealing material between the ferrule and the waveguide, an attachment adhesive for attaching the ferrule to the waveguide away from a region of the sealing material, the geometry of the ferrule being arranged such that the adhesive is prevented from wetting into a space between the seal and the adhesive.

16. A hermetic optical waveguide feedthrough assembly for a package, having a ferrule around the waveguide, and a sealing material between the ferrule and the waveguide, and a protective part around the waveguide where it leaves the sealing material, on a side of the ferrule facing into the package, to limit bending of the waveguide.

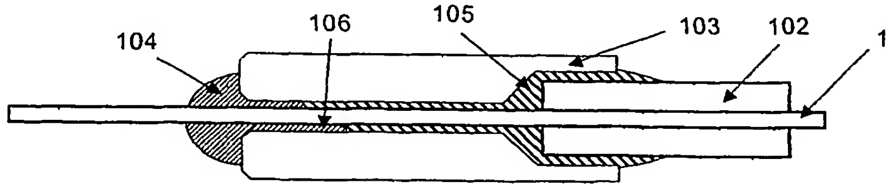
17. An optical package having one or more of the hermetic optical waveguide feedthrough assemblies of any preceding claim.

18. A method of assembling a hermetic optical waveguide feedthrough assembly, having the steps of:
attaching a spacer ferrule to the waveguide,
attaching a sealing ferrule to the spacer ferrule, and
applying a hermetic seal between the waveguide and the sealing ferrule.

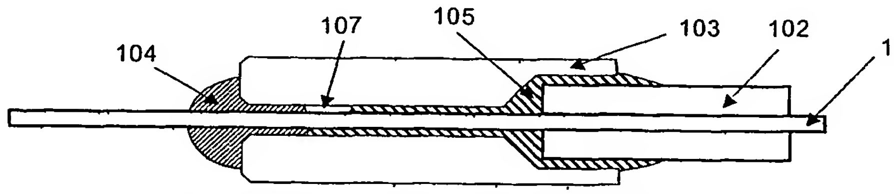
19. A method of assembling an optical package, comprising the steps of:
assembling an optical device,
assembling a hermetic optical waveguide feedthrough assembly as set out in claim 16,
attaching the optical device to the waveguide having the feedthrough assembly outside its package,
inserting the device into its package and attaching the feedthrough assembly to the package.



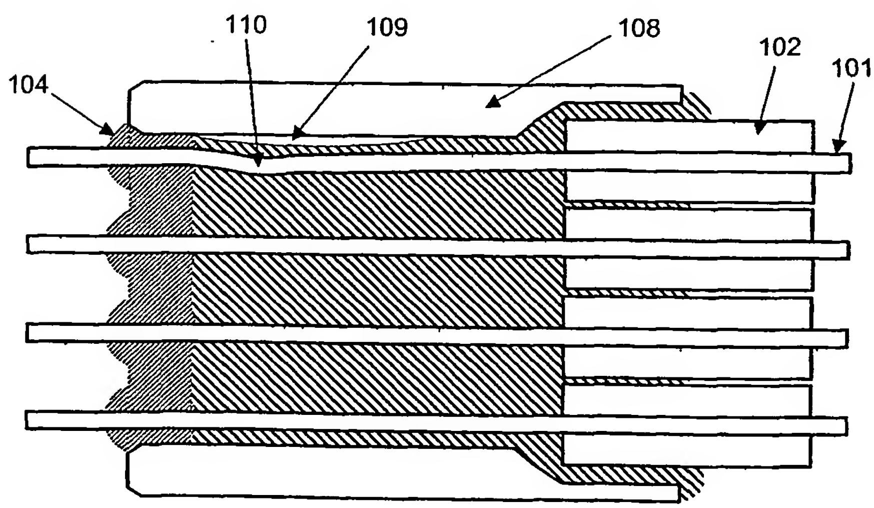
(a) prior art



(b) prior art – uneven sealant wetting

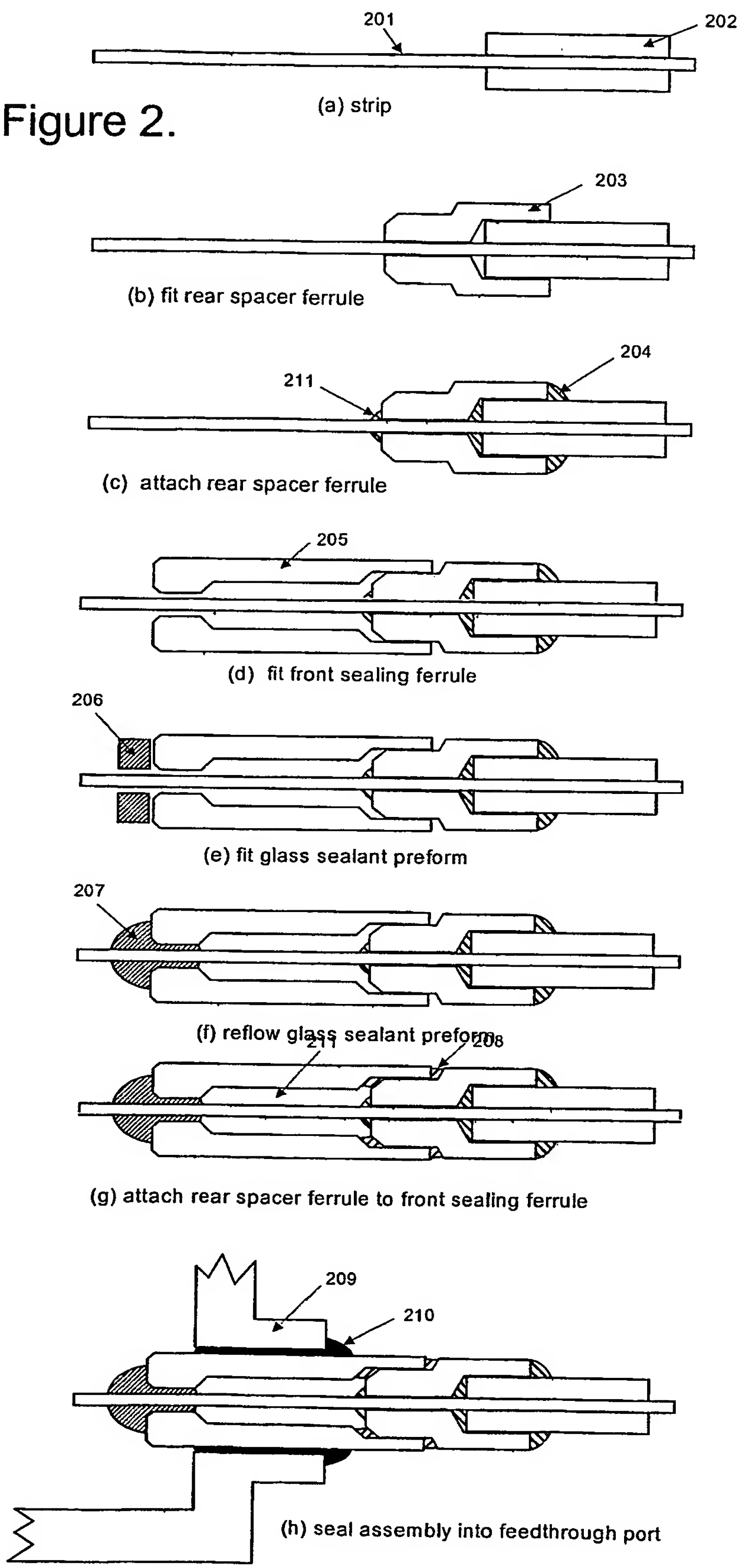


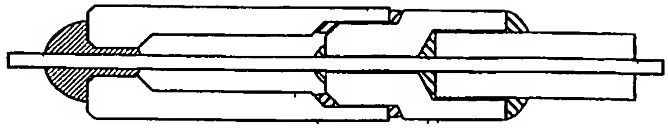
(c) prior art – void in backfilled adhesive



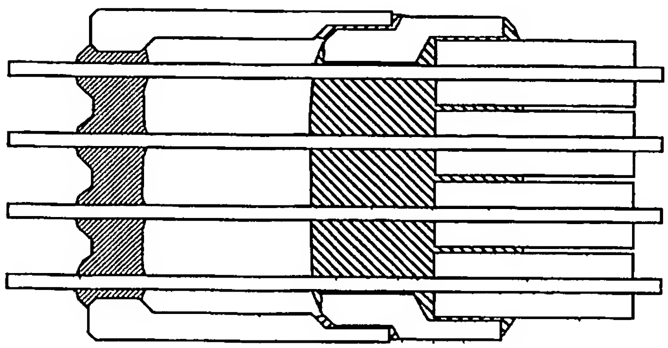
(d) prior art – cure shrinkage void in backfilled adhesive

Figure 2.


201
202
(a) strip
203
(b) fit rear spacer ferrule
204
211
(c) attach rear spacer ferrule
205
(d) fit front sealing ferrule
206
(e) fit glass sealant preform
207
(f) reflow glass sealant preform
211
208
(g) attach rear spacer ferrule to front sealing ferrule
209
210
(h) seal assembly into feedthrough port

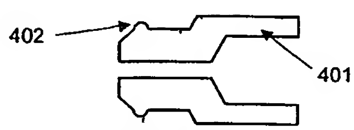


(a) side view

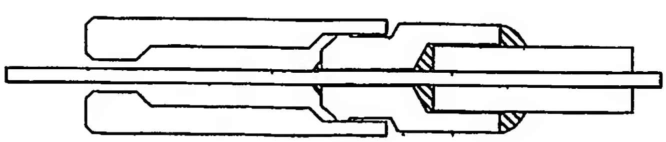


(b) top view

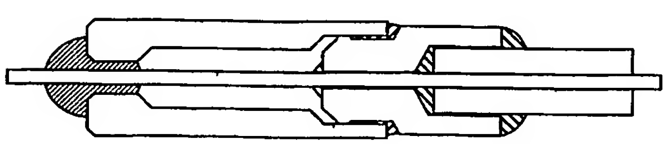
Figure 3.



(a) modified rear ferrule with flow inhibitor 'beading'

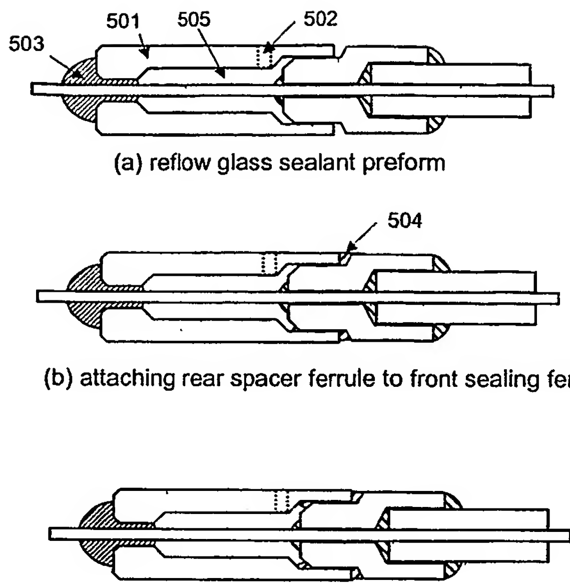


(b) interference fit of modified rear ferrule in front ferrule



(c) modified assembly

Figure 4.

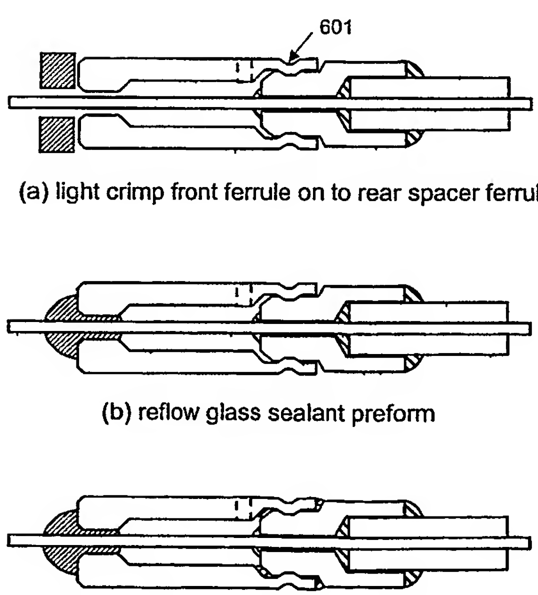


(a) reflow glass sealant preform

(b) attaching rear spacer ferrule to front sealing ferrule

(c) attached rear spacer ferrule to front sealing ferrule

Figure 5.

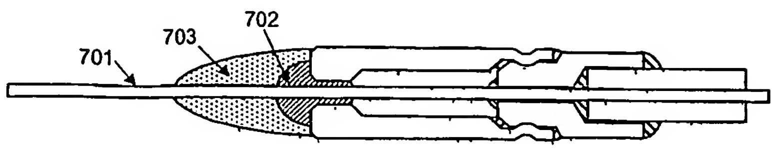


(a) light crimp front ferrule on to rear spacer ferrule

(b) reflow glass sealant preform

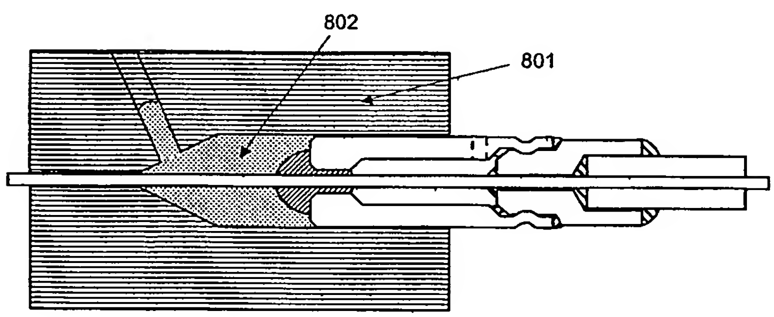
(c) attach rear spacer ferrule to front sealing ferrule

Figure 6.

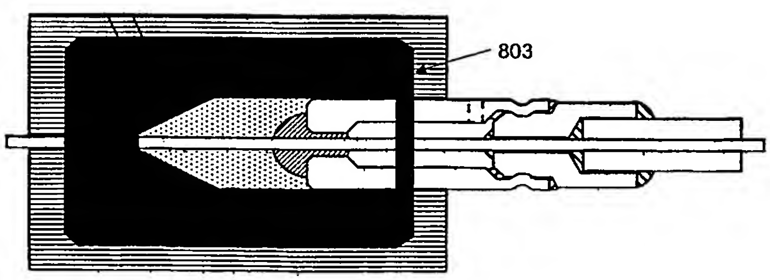


(a) partially reinstated coating to act as internal bend limiter.

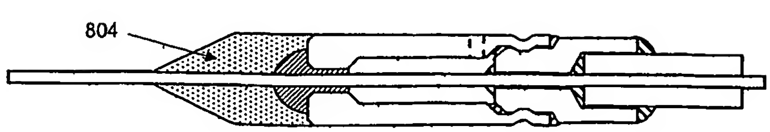
Figure 7.



(a) use of mould for reinstatement bend limiter.

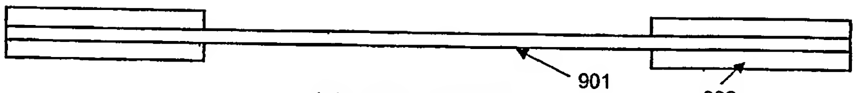


(b) uv cure reinstatement through mask.

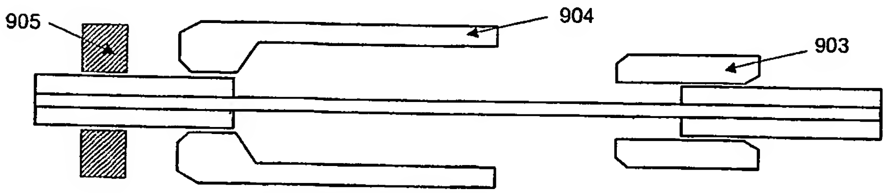


(c) moulded internal bend limiter in place.

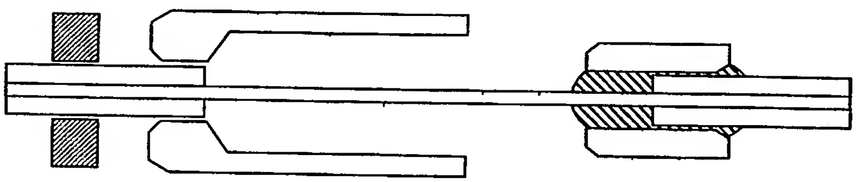
Figure 8.

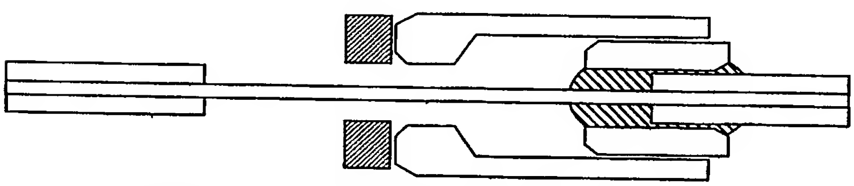


(a) centre strip fibre



(b) thread components onto fibre


(c) attach rear ferrule


(d) insert rear spacer ferrule into front sealing ferrule

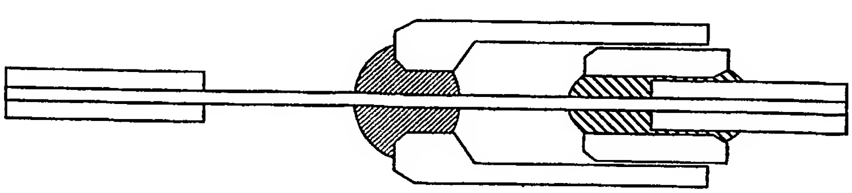
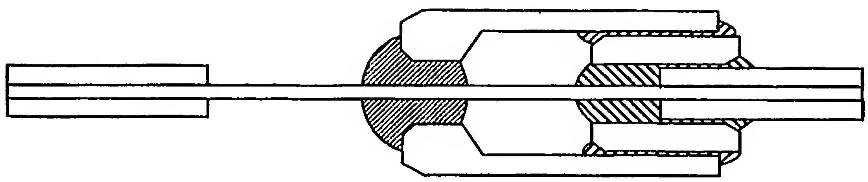
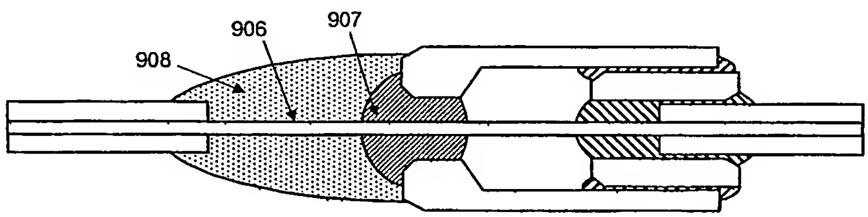

(e) reflow glass sealant preform

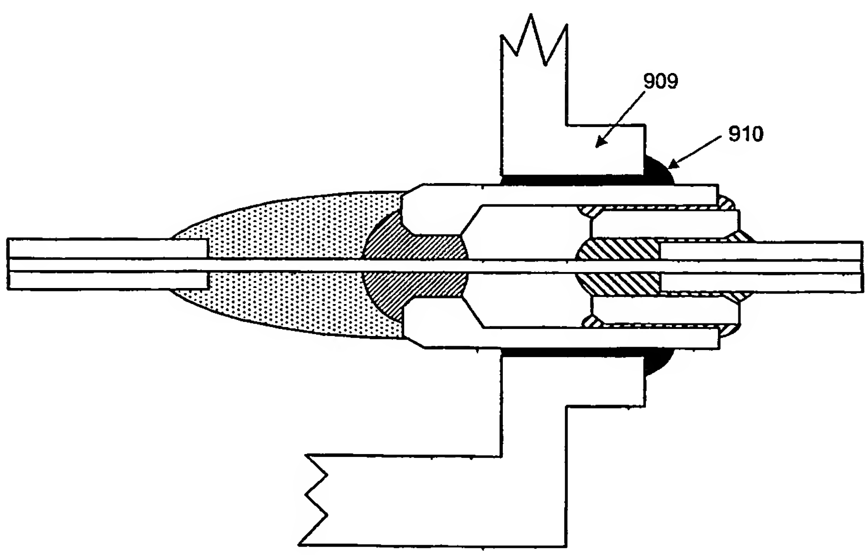
Figure 9 (a) to (e)



(f) attach rear spacer ferrule to front sealing ferrule



(g) reinstate fibre coating over hermetic seal



(h) thread and seal assembly into feedthrough port

Figure 9 (continued) (f) to (h)

Fig 10a assemble fta

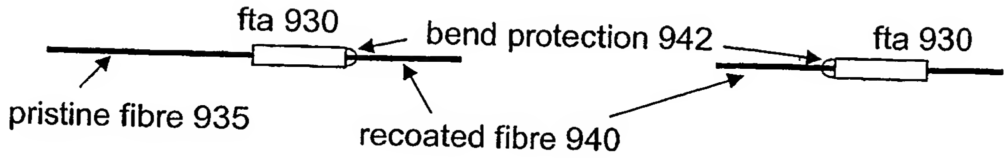


Fig 10b assemble optical device outside package

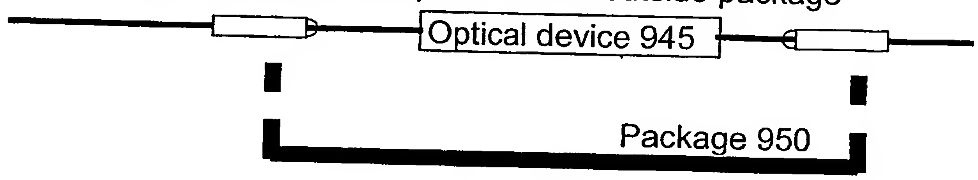


Fig 10c thread one end into package

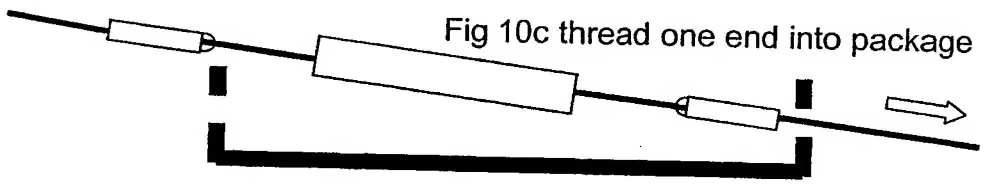


Fig 10d thread other end into package – involves bending critical lengths of reinstated fibre, unless package is unacceptably long

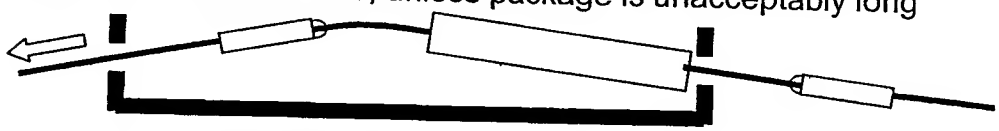
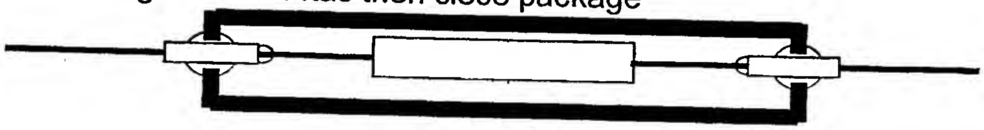


Fig 10e seal ftas then close package



INTERNATIONAL SEARCH REPORT

PCT/GB 03/02553

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 35 33 920 A (SIEMENS AG) 26 March 1987 (1987-03-26) column 5, line 14-62; figure 2	1,3-6,8, 9,12-14, 17,18
Y		7,10
X	EP 0 587 895 A (FUJITSU LTD) 23 March 1994 (1994-03-23) column 16, line 37 -column 17, line 19; figures 18,19	1,3-6,8, 9,12-15, 17,18
Y		7,10
X	EP 0 608 895 A (NIPPON ELECTRIC CO) 3 August 1994 (1994-08-03) page 4, line 17-28; figures 4,7	1,2,4, 11,17

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 October 2003	15/10/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Riblet, P

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 220 766 B1 (CORNISH ANDREW PAUL ET AL) 24 April 2001 (2001-04-24) column 3, line 19 -column 4, line 17; figures 1-6	1,3-6,8, 12-15, 17,18
Y		7,10
X	WO 00 39619 A (GOBBI LUIGI ;PIRELLI CAVI E SISTEMI SPA (IT); SCHIATTONE FRANCESCO) 6 July 2000 (2000-07-06) page 15, line 17-19; figure 3 page 1, line 1-11	16,19
Y		7,10
P,X	WO 02 069012 A (CODEON CORP ;DONALDSON ALAN (US); YAN YU (US)) 6 September 2002 (2002-09-06) abstract; figures	1,2,4, 14,15,18

INTERNATIONAL SEARCH REPORT

Information on patent family members

PCT/GB 03/02553

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
DE 3533920	A	26-03-1987	DE	3533920	A1	26-03-1987
EP 0587895	A	23-03-1994	DE	69225068	D1	14-05-1998
			DE	69225068	T2	17-09-1998
			EP	0587895	A1	23-03-1994
			JP	2962830	B2	12-10-1999
			US	5386488	A	31-01-1995
			CA	2103145	A1	03-10-1993
			WO	9320467	A1	14-10-1993
EP 0608895	A	03-08-1994	JP	2524463	B2	14-08-1996
			JP	6230231	A	19-08-1994
			DE	69429199	D1	10-01-2002
			DE	69429199	T2	02-05-2002
			EP	0608895	A1	03-08-1994
			US	5515473	A	07-05-1996
US 6220766	B1	24-04-2001	GB	2339300	A	19-01-2000
			AU	3949299	A	24-01-2000
			CA	2336626	A1	13-01-2000
			CN	1308733	T	15-08-2001
			DE	69909797	D1	28-08-2003
			EP	1093593	A1	25-04-2001
			WO	0002079	A1	13-01-2000
			JP	2002520634	T	09-07-2002
WO 0039619	A	06-07-2000	AU	1973100	A	31-07-2000
			CA	2356978	A1	06-07-2000
			WO	0039619	A2	06-07-2000
			EP	1145062	A2	17-10-2001
			JP	2002533780	T	08-10-2002
			TR	9903237	A2	21-07-2000
			US	2002037144	A1	28-03-2002
WO 02069012	A	06-09-2002	WO	02069012	A2	06-09-2002
			US	2002122653	A1	05-09-2002